SAMPLING AND MEASUREMENT ERROR

PART 1: SAMPLING ERRORS

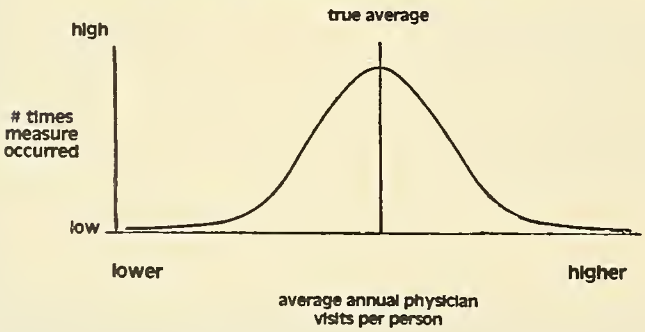
Purpose and Overview

The intent of this two-part "statistical primer" is to provide the reader with an understanding of basic concepts of errors in estimates. Sampling a population in order to estimate population characteristics may result in estimation errors. It is less widely recognized that measures based on a "complete count" may also have a substantial error component. This presentation should provide the reader with the background needed to interpret and evaluate rates and other health-related measures, and to understand basic discussions of measurement error in statistical papers. Discussions of random vs. nonrandom and sampling vs. nonsampling errors are first presented. An explanation of random sampling error leads to the development of formulas for quantifying the sampling errors of means and proportions. In addition, a guide to carrying out simple random sampling procedures is provided, which could be used to gather needed information in a practical setting such as the local health department. In Part 2, the estimation of the error involved in vital and other rates based on a complete enumeration of events is described, and a method for determining the statistical significance of a difference between two rates is presented.

Random vs. Nonrandom Errors

Most assessments of sampling or measurement variability are based on the concept of random errors. Repeated estimates may overstate or understate the underlying or "true" value of interest, but it is usually assumed that the errors of measurement are random in nature and correspond to a known distribution. For example, it is commonly assumed that repeated estimates of a population characteristic would form a bell-shaped curve or **normal distribution** if plotted on paper (see Figure 1). This would be true whether the characteristic were estimated through samples from a population or through quantifications based on all elements of the population, though in the case of a sample the variability from one estimate to the next will usually be greater.

FIGURE 1:
Typical Normal Distribution:
Repeated Measures of a Population Characteristic



In the physical sciences, as well as in the less precise health and social sciences, errors of measurement are important to consider. Even the simple measurements of the length of a rod are found to vary. The "error" of such individual measurement is sometimes positive and sometimes negative, but the average of a number of repeated measurements usually becomes more and more steady as the number of measurements increases, and converges on the "true" value even though the magnitude of error in a single measurement is unknown. Thus the concept of probability has become an important part of the theory of scientific measurement. For most of human history absolute certainty has been considered an essential condition for genuine knowledge. Recently, however, "in the whole field of science the deductive-mathematical process of absolutely certain inference is being replaced by the probabilistic-statistical method of uncertain inference" (1). If science is based on observation and measurement and if each set of measurements is a statistical sample, then all scientific conclusions are subject to a margin of uncertainty. It is the job of statistics to quantitatively estimate the degree of this uncertainty.

In some cases there may be a consistency of errors leading to a definite bias. In these cases of nonrandom errors the usual statistical tools, which depend on the concept of randomness, are of limited help. It is still important, however, to consider possible measurement biases since these errors can undermine the best efforts to assess and control the random error component.

Sampling vs. Nonsampling Errors

Taking a sample or subset of a population in order to estimate a characteristic of the whole population will involve some degree of sampling error, because the characteristic is estimated from a population subset rather than from the entire population. If a sample is drawn in a random fashion, probability theory enables us to evaluate the likely degree of sampling errors, i.e., those errors introduced because samples vary from one to the next. Nonsampling errors, on the other hand, are errors of measurement and may be more or less random, or they may be systematic errors leading to a bias as was mentioned above. There is nothing to be gained in reducing sampling errors below a certain point as compared with nonsampling errors. If nonsampling mistakes such as response or interviewing errors are large, there is no point in taking a huge sample in order to reduce the sampling error component since the total error will still be large. (2) Though this paper deals principally with the question of sampling error, it is very important to be aware of and attempt to reduce the nonsampling errors that will occur in a sample survey project.